Mn/DOT

Mileage-Based User Fee Demonstration Project

Technology Inventory and Assessment

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Submitted to:

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List of Acronyms Used in Report

AVL – Automated Vehicle Location

CDMA – Code Division Multiple Access

CDPD - Cellular Digital Packet Data

DC – Direct Current

DMI – Distance Measurements Instruments

DSRC – Dedicated Short Range Communications

GPRS – General Packet Radio System

GPS – Global Positioning System

GSM – Global System for Mobile communications

LAN – Local Area Network

MW - Microwave

OBD – Onboard Diagnostics Device

RF – Radio Frequency

RFID – Radio Frequency Identification

TDMA – Time Division Multiple Access

TOD – Time of Day

VMT – Vehicle Miles Traveled

VSS – Vehicle Speed Sensor

1. Introduction

The Minnesota Department of Transportation (Mn/DOT) has contracted Cambridge Systematics, Inc. to develop and conduct a Mileage-Based User Fee Demonstration Project to test price elasticities of driving behavior by offering financial incentives and by simulating the replacement of fixed costs of ownership/leasing and operation with fees based on mileage and perhaps time of day (TOD) travel. There is a range of solutions available that can collect the data necessary to calculate these mileage-based (and TOD-based) user fees; these solutions vary from no/low to high technology sophistication. This report contains an inventory and assessment of these solutions, and recommendations for the Mn/DOT project.

2. Background

The concept of charging road users fees for their actual usage has been around for many decades. Toll roads are one obvious implementation of this pricing scheme, with users paying either a fixed fee or variable fee based on miles of travel on a limited access roadway. These tolls are typically collected at fixed locations of roadway access or egress.

With the advent of mobile technologies for tracking mileage, fixed toll infrastructures are no longer necessary or practical as more sophisticated, dynamic strategies are required for system-wide (i.e., regional or statewide) congestion relief. Beyond mileage-only pricing schemes, recent applications of congestion pricing have added both temporal and spatial components to the road user mileage-based fee structure. For example, some congestion pricing strategies charge users for travel only during peak travel hours (referred to as time-of-day or TOD pricing), while other strategies charge only for specific network-link or facility-type usage.

A range of low to high technology solutions exists to support mileage-based, TOD-based, and location-based pricing. These solutions enable the collection of vehicle miles traveled (VMT), trip start and end times, and/or vehicle route data for use in user fee assessments. Table 1 shows the various user fee pricing schemes enabled by capturing increasing levels of detail.

Table 1: Data Needs for User Fee Pricing Strategies

Data Available	Pricing based on:
mileage	total miles traveled
mileage trip start & end times	occurrence of travel within specific TOD
mileage trip start & end times trip route	total miles traveled within specific TOD* total miles traveled within given geographic boundary / zone total miles traveled on specific network links total miles traveled on specific network links within specific TOD

* This could also be supported with the collection of intermittent speeds instead of locations

In general, as the level of detail required to support various pricing strategies increases, the sophistication of the technology solution increases. Consequently, the following assumptions were made for the technology inventory and assessment task based on the level of detail required:

1) **Collect mileage only**: Manual methods will suffice – technology solutions are overkill if mileage is the only variable required.

2) **Collect mileage and times**: To collect trip level information including mileage and trip start and end times, automated methods are the only reasonable solution for long-term studies such as this one.

3) **Collect mileage, times, and routes**: Once route details are added to the data requirements, Global Positioning System (GPS) based automated solutions are the only feasible solution.

The scope of work for this study specifically asked for the evaluation of mileage-based user fees, with a possibility of adding time-of-day pricing. Therefore, the minimum data collection requirements for this study are the collection of trip-by-trip mileage and times. To support time-of-day pricing that involves mileage-based fees based on the portion of travel within a specific time period, some type of intermittent logging of positions or speeds would also be required.

3. Functional Requirements

The following equipment and data transfer functional requirements were created as a baseline against which the various technology solutions inventoried were compared. To ensure an adequate assessment of technology / product capabilities by the research team, these requirements were provided and reviewed in detail with the vendors whose products appear to be a close match for the Mn/DOT study.

3.1 Equipment Requirements

It is anticipated that the technology solution(s) for this study will be deployed in the Minneapolis – St Paul region for a one-year period per vehicle. All equipment will need to meet all requirements of the study for the full duration of deployment.

Mileage and Trip Time Logging

- For each trip made (determined by successive engine on and off events), record distance traveled, start time, and end time
- Transmit trip data (since last successful transmission) and control information (such as date and time period, vehicle/unit ID) through wireless data transfer on weekly basis
- Log and transmit (along with other transmission) total distance traveled since start of study for quality control purposes
- Transmission can be pre-scheduled, and if cellular network not available, system should transmit at next available time
- Need remote method for polling non-reporting units
- Clear previously stored trip data upon successful transmission if necessary for storage capacity considerations
- Powered by vehicle
- Easy to install, unobtrusive and noninvasive (minimal installation time)
- Tamperproof to maximum extent possible with logging of non-tamperproof events (ie, power removed, antenna removed)

Mileage, Trip Time, and Location Logging

- For each trip made (determined by successive engine on and off events), record distance traveled, start time, and end time
- Capture GPS coordinates along with date and time stamps periodically based on predefined logging rules (e.g., one point every 0.1 miles traveled)
- Transmit distance and GPS data (only that collected since last successful transmission) and control information (such as date and time period, vehicle/unit ID) through wireless data transfer on weekly basis
- Log and transmit (along with other transmission) total distance traveled since start of study for quality control purposes

- Transmission can be pre-scheduled, and if cellular network not available, system should transmit at next available non-peak time
- Need remote method for polling non-reporting units
- Clear previously stored GPS and trip data upon successful transmission
- Powered by vehicle
- Easy to install, unobtrusive and noninvasive (minimal installation time)
- Tamperproof to maximum extent possible with logging of non-tamperproof events (ie, power removed, antenna removed)

3.2 Assumptions for Data Storage and Transmission Estimates

These baseline data element collection and transmission requirements were provided to vendors who stated that their products could meet the Mn/DOT project requirements including a wireless (cellular) data transfer capability.

Mileage and Trip Time Logging

- Collect start and end times for each trip detected by engine on / off event (YYYY, HH:MM:SS for each)
- Calculate and store mileage for each trip (XXX.X miles traveled)
- Assume worst case 20 trips per day (use for unit capacity considerations)
- Assume average case 8 trips per day (use for transmission cost estimates)
- Transfer data file with trip start time, end time, and mileage at off-peak transmission hours at least once a week

Mileage, Trip Time, and Location Logging

- Collect start and end times for each trip detected by engine on / off event (YYYY, HH:MM:SS for each)
- Calculate and store mileage for each trip (XXX.X miles traveled)
- Collect GPS point data (time, latitude, longitude, heading, speed) for every 0.1 miles traveled
- Assume worst case 20 trips per day, total daily mileage of 300 miles (use for unit capacity considerations)
- Assume average case 8 trips per day, total daily mileage of 45 miles (use for transmission cost estimates)
- Transfer data file with trip start time, end time, GPS data, and mileage at off-peak hours at least once a week

4. Inventory Results

Technologies options were identified through web searches, product advertisements, project reports, research papers, local university libraries, and vendor contacts. Best practices were also identified through similar means, focusing on current or past projects with related objectives. Suitable technological solutions were further investigated through direct vendor contact to obtain additional information regarding specifications, availability, and cost.

The technology review identified a variety of mileage-logging solutions that involve a direct physical connection to a vehicle. These solutions include onboard diagnostics system (OBD) sensors, vehicle speed sensors (VSS), distance measurement instruments (DMI), and custom sensors. In a separate category, GPS-based solutions operate independently of a given vehicle and can calculate distance traveled using position information gathered along the vehicle's travel path.

Numerous data transfer technologies and methodologies were identified for moving the information collected from the vehicle to a central data storage location for processing and billing. At the no / low technology end of the spectrum, a person can either read a display (such as the odometer) or connect a cable to a sensor to download the data. At the high end of the spectrum, wireless data transfer can be conducted locally through microwave or RF communications (known as Dedicated Short Range Communications or DSRC), or remotely (i.e., region-wide) using cellular communications.

This research also revealed the existence of similar projects or technology applications. These projects and/or applications are summarized in Table 2. If possible, information was obtained for each example listed. Given the similar objectives of this project with others within the Federal Highway Administration (FHWA) Value Pricing Program, an inventory of relevant studies was conducted, with summaries contained in Appendix A. If technology solutions either under consideration or selected for these studies were applicable to this project, then they were included in the appropriate technology category.

Table 2: List of Relevant Application Areas

Application	Primary Purpose	Examples
Commercial fleet mileage tracking	audit drivers vehicle maintenance	Trucking firms Utility companies
Commercial fleet operations	operations management / dispatching	AVL / Transit Operations On Demand Courier Services
Mileage-based insurance rates	insurance rates based on miles traveled	Progressive Insurance Norwich Union Insurance
Mileage-based user fees - trucks	road fee based on miles traveled	Swiss Heavy Vehicle Road Pricing German Toll-Collect for Truckers
Mileage-based user fees - autos	value or congestion pricing	Mn/DOT Puget Sound Regional Council Oregon DOT Atlanta MA - CLF Ventures*

* This grant was not awarded

Table 3 shows a range of solutions available across the technology spectrum. The inventory and assessment sections that follow are broken into two categories – non-GPS and GPS solutions. Within each category, products that support wired and wireless data transfer are included.

Table 3: Range of Feasible Methodologies and Technologies for Mn/DOT Study

	Data Collection	Data Transfer	Comments
Low Tech	Self-reporting odometer reading	paper mail-in / telephone retrieval	1) good for mileage only, although a trip log with start time, end time, and mileage could be kept
	Field staff odometer reading	paper recording	1) good for mileage only, more accurate method 2) requires vehicle(s) to be present
	Self-reporting odometer reading	website reporting	1) good for mileage only, although a trip log with start time, end time, and mileage could be kept 2) more timely data availability 3) more accurate data with error checking
	Field staff odometer reading	Palm handheld recording	1) good for mileage only, more accurate method 2) requires vehicle(s) to be present
	Non-GPS technologies	Field staff visit – download or memory card swap	1) good for mileage and trip times if supported 2) if not, odometer reading is sufficient 3) requires vehicle(s) to be present
	GPS technologies	Field staff visit – download or memory card swap	1) good for mileage, trip times, and route 2) requires vehicle(s) to be present
	Non-GPS technologies	mail out / back memory card swap	1) good for mileage and trip times if supported 2) if not, odometer reading is sufficient 3) eliminates field visit but requires respondent to swap card
	GPS technologies	mail out / back memorycard swap	1) good for mileage, trip times, and route 2) eliminates field visit but requires respondent to swap card
High Tech	Non-GPS technologies	wireless - Short range or cellular	1) good for mileage and trip times if supported 2) if not, odometer reading is sufficient 3) requires vehicle to be in proximity of reader for SR
	GPS technologies	wireless – Short range or cellular	1) good for mileage, trip times, and route 2) sufficient cellular coverage is needed across region 3) requires vehicle to be in proximity of reader for SR

4.1 Non-GPS Mileage Logging Technologies

This category includes technology solutions that do not use GPS as a means for calculating distance traveled. In general, products in this category require a direct connection to one of the vehicle's systems or components (e.g., axle, onboard computer, or vehicle speed sensor) to measure speed or distance traveled.

4.1.1 Inventory

Examples of technologies that connect directly to a vehicle's mechanical system for measurement of speed or distance traveled include:

- **Distance Measurement Instrument (DMI)** – devices that involves the installation of a custom axle or wheel sensor, followed by calibration, to measure distance traveled.
- **Onboard Diagnostic Sensor (OBD)** – devices that connect to a vehicle's computer interface for observing or recording engine parameters including speed.
- **Vehicle Speed Sensor (VSS)** – devices that are connected directly to the vehicle's speed sensing system.
- **Electronic Hubodometer** – devices that use an internal electrical pulse sensor pulse triggered by tire rotation.
- **Custom Sensors** – 'black boxes' built for a specific application that ties into various vehicle systems.

Table 4 lists a representative sampling of these technologies. Complete product descriptions are included in Appendix B for each item listed here.

Table 4: List of Reviewed Non-GPS Products

Product	Company Name	Website	Technology Type
AT5770	TransCore	www.transcore.com	VSS
Auto Watch	Ease Diagnostics	www.obd2.com	OBD II
Carchip EX	Davis Instruments	www.davisnet.com	OBD II
DataTrac	Stemco	www.stemco.com	Electronic Hubodometer
Mobile Minion	AFX Technologies	www.afxtech.com	OBD II or VSS
Mileage Keeper	Wilderness Technology	www.wildtec.com	VSS
Mileage Master	Mileage Master	www.mileagemaster.com	VSS
NITESTAR 50	Nu-Metrics	www.nu-metrics.com	DMI
Tacholink	Circuitlink International	www.circuitlink.com.au	VSS
Zipcar	Zipcar	www.zipcar.com	Custom Sensor

4.1.2 Assessment

Only a few products in this category are capable of capturing trip times, which would allow time of day pricing based on occurrence of travel within a time period. One product, the Carchip, can also capture intermittent speeds, which could be used to derive distance traveled within certain time periods.

Most of these devices require direct connectivity to one of the vehicle's systems or components, which could require a high level of skill required for installation, as well as a significant amount of installation time. Some of these units were designed to be seen by the driver, and are therefore quite intrusive. In addition, these devices often require calibration for accurate measurement, which could include inputting vehicle details such as wheel size or driving the vehicle over a fixed distance. Some devices require specific models or connectors for different vehicle types. Many devices in this category support limited onboard storage without wireless data transfer capabilities, which would require frequent visits by field staff for data downloads.

Taximeters, a type of VSS that are designed to compute a fare based on distance traveled, were not considered in this assessment due to the user-interface component of the device (i.e., the driver must manually engage the device by pressing a button to begin logging a trip). In addition, the device is designed to display the "Fare", functionality that is unnecessary for this project.

Only four out of these nine products featured wireless data transfers (AT5770, Mobile Minion, Tacholink, and Zipcar), with the remaining units requiring either a serial cable connection (RS 232), or a visual read to transfer or record the logged data. Of the four wireless solutions, the first two require a local radio frequency (RF) reader, the Tacholink uses a memory card, and Zipcar offers cellular transmittal of trip details.

4.1.3 Best in Category

Due to size, installation requirements, and / or calibration needs, the DMI, VSS, and electronic hubodometer products are not practical solutions for the Mn/DOT study. Both OBD II sensors and custom sensors could meet the requirements of this study. Unfortunately, custom sensors tend to be quite expensive and most of the manufacturers currently competing in this market are not interested in implementing the changes needed for this study.

Therefore, by default, OBD II sensors are the best product in this category. The key limitation of OBD II products is that vehicle model years prior to 1996 are not supported. Although many OBDII products were originally designed for in-garage or testing use only, The Carchip produced by Davis Instruments is an incredibly small and easy-to-install device that meets the needs of the Mn/DOT study. A summary of this product follows.

Carchip EX / Davis Instruments

Description: Small device that plugs to the OBD II port and records either 75 or 300 hours of vehicle activity (two models available). Trip start and end times, along with mileage, are automatically collected.

Assessment: This device automatically collects trip details needed for this project as well as the date and time stamp of each installation and removal. The 300 hours of recording capacity will collect 100 days of activity assuming 3 hours of travel per day. The basic model, with 75 hours of recording capacity, will collect one month of activity assuming 2.5 hours of travel per day. The Carchip works only in 1996 and later model years.

Technology: OBD II **Requires Calibration:** No

Power: 12V (through OBD port), internal power 10-15 year battery

Operating temperature: -40° to +185°F

Accuracy: Speed - 0 .6 mph, Distance - 0 .1 mile, Time - +/- 2 seconds per day

Size: 1.3 x 1.9 x 1 (inches)

Communication Method: Powered RS 232 cable

Unit Cost for Quantity Purchase: $161 for 300 operating hours / $125 for 75 operating hours

4.2 GPS Mileage Logging Technologies

Typical in-vehicle GPS product components include a GPS receiver and antenna, a microprocessor (the control unit and logic), a data storage device (internal or memory card), and a data transfer mechanism (wired, memory card, or wireless).

4.2.1 Inventory

The inventory process for GPS-based products generated three subcategories based on method of data transfer: GPS with wired download; GPS with memory card; and GPS with wireless communications. Table 5 lists a representative sampling of these technologies. Complete product descriptions are included in Appendix C for each item listed here.

Table 5: List of Reviewed GPS Products

Product	Company Name	Website
GPS Devices (wired)		
TravelEyes2	Advanced Tracking Technologies, Inc	www.traveleyes.com
GeoLogger	GeoStats	www.geostats.com
GPS Devices with Memory Card		
GD30-L	Laipac Tech	www.laipac.com
TracWise I	Hamilton Global Management	www.tracwise.com
VBOX II Lite	Racelogic	www.racelogic.co.uk
GPS Wireless Devices		
Aertrax III	AerComTec International	www.aercomtec.com
Aertrax V	AerComTec International	www.aercomtec.com
BBX	Mentor Engineering Inc	www.mentoreng.com
eDevice	IBM/Celestica	www.ibm.com
Fleet Real-time Tracker	123 Vehicle Tracking	www.123-vehicle-tracking.com
Geomanager iLM	@Road	www.atroad.com
Shadow Tracker 2000	Advanced Tracking Technologies	www.traveleyes.com
Starfinder AVL	Laipac Tech	www.laipac.com
Trackbox	Airo Benefon	www.benefon.com
VLM-100	TransTel Group Inc.	www.transtelgroup.com

4.2.2 Assessment

The inclusion of GPS technology in these products provides a solution that is vehicle independent in that no direct connection is needed to the vehicle except for power (and ignition sensing, if exact trip start and end times are desired). Therefore, equipment installation is much more straightforward and standard across all vehicles in the study. There are hundreds of GPS-based vehicle products on the market today. Those that include cellular communications are often referred to as telematics. Several large firms, including IBM and DaimlerChrysler, are making a strong entry into the 'black box' telematics field, with products hitting the market this year.

GPS solutions that log GPS traces usually require a wired or memory card download and are typically designed for specific applications (such as fleet, tracking, undercover surveillance or household travel surveys), making them impracticable for this study from a cost perspective due to the large amount of GPS data collected. GPS products that offer cellular data transfer usually do not log and transfer high-resolution GPS data (as this can get expensive); they are typically designed to answer the question 'where is the vehicle now?' Examples of these products include those that meet the needs of in-vehicle navigation, roadside assistance, E911, theft recovery, or parole violation detection. There is also a class of highly specialized systems that collect specific GPS information and tap into multiple vehicle sensors to meet a given application (such as fleet management or dispatching).

Although there was no GPS product found that met the exact requirements of this study, there were several identified that could work with minor modifications. Given the aggressive timeline for implementation for the Mn/DOT project, products requiring significant modification were eliminated from further consideration.

4.2.3 Best in Category

Three products might work for this study. The first product uses a 32MB memory card for GPS data logging and transfer. The GD30-L made by Laipac Tech meets the project needs for mileage and trip time capture, and exceeds the requirements by providing detailed second-by-second location data. The second and third products identified (IBM/Celestica's eDevice and Airo Benefon's Trackbox) both offer a integrated GPS logging and cellular solution with some customization required.

GD30-L / Laipac Tech

Description: GPS recorder and vehicle tracking system with memory card technology for the storage of a large amount of GPS tracking data. The memory card's size and parameter settings can define the length of the time for recorded data. The included 32MB MMC card can record up to 400,000 GPS waypoints

Assessment: This product could log the necessary data for this project.

Required modifications: Few if any

Power: 5-12V DC with backup battery capability

Operating Temperature: -22^{o}C to +75^{o}C

Communication Method: 32 MB memory card

Accuracy: Distance – 29 feet, Time - 1 Hz/sec update, 1804 f/sec maximum

Size: 3.7 x 5.3 x 1.8 (inches).

Website: www.laipac.com/gps_gd30l_eng.htm

Unit Cost for Quantity Purchase: $225

eDevice / IBM Celestica

Description: These electronic monitoring devices for cars are being promoted as black boxes based upon industry open standards. They will wirelessly transmit information from vehicles to specific

databases, providing information on a wide range of variables including speed, location, or use of seatbelts – entirely as specified by each customer.

Assessment: This product looks promising, although it is not commercially available yet. One project that has started in the UK will use the eDevice for a "Pay-As-You-Drive" pilot insurance program offered by Norwich Union, the UK's largest auto insurer.

Required Modifications: minor

Power: 12V DC

Operating temperature: No information available

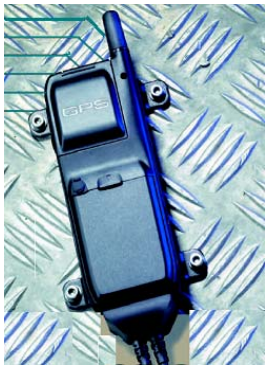
Communication Method: GSM/GPRS modem

Website: www-1.ibm.com/industries/automotive/doc/content/news/pressrelease/875975108.html

Unit Cost For Quantity Purchase: $400 each plus transmission / central storage / system integration costs (which could be substantial)

Trackbox / Airo Benefon

Description: A cellphone-like product with built in GPS logging and cellular transmission using the GSM cellular network. An emergency call button can be included to send an emergency message with GPS coordinates.



Assessment: This product has a small profile and is appears to be easy to install. The device is designed for GPS logging and data transmission.

Required Modifications: Increased storage capability between downloads and mileage-based logging logic.

Power: 10–30V DC input, backup - standard 650 or 1700 mAh Li-ion battery

Operating temperature: –22° to +55°C

Communication Method: GSM cellular network

Size: 5.7 x 2 x 1.3 (inches)

Website: www.benefon.com/usa

Unit Cost For Quantity Purchase: $450 each plus transmission / central storage costs

4.3 Local Area Wireless Data Transfer Solutions

As defined by the U.S. Department of Transportations ITS Standards program, Dedicated Short Range Communications (DSRC) technology is a system of two-way communication between vehicles, or a vehicle and a roadside infrastructure, e.g., a RF unit/tag/antenna structure in the vehicle and a roadside reader. Communication between the vehicle and roadside reader typically cannot exceed 1000 meters and often must be significantly closer (e.g., TransCore offers a range of tags that can only be read at distances less than one foot up to 800 feet). DSRC includes Radio Frequency (RF) technology that operates below 3 GHz and Microwave technology (MW) which functions within the bandwidth range of 1- 30GHz. The most common RF band used for transportation solutions is the 902 – 928 MHz band (also referred to by its midpoint of 915 MHz or more generically as the 900 MHz band). In the Microwave category, 5.8 GHz is the most commonly used frequency band, which has a plus or minus 75 MHz tolerance.

The most significant difference between high-frequency RF and super-high frequency MW to be considered for this study concerns the trade-off between "propagation losses" (signal diffusion), signal attenuation due to atmospheric conditions (e.g., smog, rain), and transmission range. The potential for signal diffusion and attenuation will be greater for higher frequency systems (MW), but the transmission range is longer. In addition, RF technologies in the 800/900 MHz bands may be more appropriate for urban areas rather than MW bands due to signal reflections from buildings.

Several devices in this technology inventory use RF transmission as the primary data transfer technology; these include TransCore's AT5770, AFX's Mobile Minion in the non-GPS product category, and the AerComTec Aertrax V and Advanced Tracking Technologies ShadowTracker 2000 in the GPS product category.

A MW technology solution to heavy-vehicle road tolling has been implemented in Switzerland by Fela Management. This system was developed to operate in the 5.8 GHz band in part to correspond with this standard across many European roadways. The German Toll Collect

system rolling out this year is currently focusing on a different approach from the Swiss; the GSM/GPRS cellular network will be used for all data transfer.

The choice of available wireless technologies, including RF, MW, and cellular will inevitably require concessions based on transmission and infrastructure costs, the range of data communications (low-frequency RF will require a higher number of road-side readers than high-frequency MW, whereas cellular transmissions do not require any local readers), and quality or temporal resolution of data (e.g., higher propagation loss in MW frequency range). For this study, cellular technology is recommended over local area wireless solutions due to the regional geographic scope and the impracticality of installing readers at convenient locations across the study area.

4.4 Wide Area Wireless Data Transfer Solutions

There are two feasible communications solutions that support wide area wireless data transfer – cellular and satellite communications. Satellite communications are impractical due to the high transmission and subscription costs, so only cellular communications were considered for this study.

Several companies offer adequate digital cellular coverage within the larger Minneapolis / St. Paul region. The extent of digital coverage drops off significantly in the more rural parts of the state. Protocols of TDMA, CDMA, and GSM are all available in the area. Nextel uses its own unique digital protocol (iDEN) using frequencies usually reserved for two-way radios and is more like mobile radio. Here is a list of the standard protocols and their descriptions:

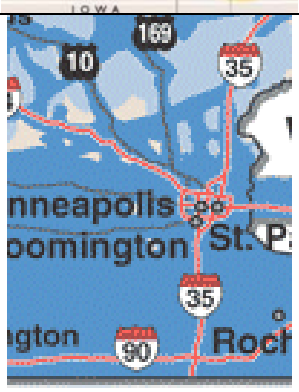
1. **Time Division Multiple Access (TDMA)** – TDMA splits conversations into pieces so that more than one conversation can exist on the same channel. TDMA is therefore limited in the number of conversations per channel, and therefore requires more towers. This is only a problem if interference occurs from the frequent switching from one tower to another. In Minneapolis, only AT&T provides TDMA protocols.

2. **Code Division Multiple Access (CDMA)** – CDMA uses a spreading technique to discern between conversations. CDMA is more efficient in the capacity and therefore requires fewer towers. This means that rural areas are more likely to have better coverage with CDMA. They have excellent quality and low power draw. In Minneapolis, four companies provide CDMA; Sprint PCS, Verizon, Qwest, and Midwest
3. **Global System for Mobile communications (GSM) –** GSM is an open standard variation of TDMA, is the industry standard in Europe, and is rapidly expanding within the US. It has advantages for users that frequently travel between different countries. AT&T and T-Mobile provide GSM in Minneapolis.
4. **Cellular Digital Packet Data (CDPD) –** CDPD is technology for transferring data using unused cellular channels at up to 19.2 Kbps. AT&T provides CDPD with good coverage of the Minneapolis / St. Paul area. No other vendors cover this area.
5. **General Packet Radio System (GPRS)** – GPRS is GSM technology for transferring data at speeds up to 171 Kbps. AT&T and T-Mobile provide GPRS in the Minneapolis area.
6. **3G-** 3G refers to the next generation of technologies that will soon be available and offer much faster data transfer rates.

Table 6 lists companies in the Minneapolis / St Paul region that provide sufficient digital network coverage for this study using one of the standard protocols listed above.

Recent support and expansion of the GSM / GPRS networks suggest that this protocol will continue to expand its coverage area within the Minneapolis / St Paul region. Telematics providers have also shifted their development effort to GSM technologies for GPS transmissions. Therefore, it is recommended that this study use GSM if a cellular solution is selected.

Table 6: Cellular Companies with Standard Digital Networks

Company	Coverage	Protocol	Pros	Cons
AT&T		TDMA, GSM, GPRS, CDPD	Inexpensive	Poor statewide coverage, limited GSM, digital not available in far southwestern suburbs of Minneapolis
VERIZON		CDMA	Coverage is good in southern half of state	Call quality / service is sometimes poor, especially in rural areas
T-MOBILE		GSM, GPRS	Inexpensive regional rates, coverage around Minneapolis is good	No roaming backup in rural areas
SPRINT PCS		CDMA	Consistent quality, inexpensive	Spotty urban coverage, high off-network fees

5. Recommendations

After inventorying the various technologies available for the Mn/DOT study, the tradeoffs between the technologies and their attributes became evident. Table 7 shows a comparative assessment of each technology solution for each required or desired project attribute where one star reflects the lowest (or poorest) rating and three stars represents the highest (or best) rating.

Table 7: Tradeoff Matrix of Technologies and Attributes

Attribute	OBDII	GPS/MC	GPS/cellular
Fleet coverage	**	***	***
Level of automation	**	**	***
Ease of installation	***	**	*
Tamperproof	*	**	**
Tamper detection	**	*	**
Other uses of data	**	***	***
Minimal tech challenge	***	**	*
Time to field	***	***	**
Inexpensive	***	**	*

Given that this project has an aggressive timeline and a limited budget for the technology component, the lower level technologies such as the OBDII or GPS with memory card might be the only feasible solutions. However, the GPS and cellular solutions are attractive in that no additional data collection field labor is required once the equipment is installed and the entire data collection, data collecting, and data processing can be fully automated.

On the no / low-tech to high-tech solutions scale, there are several products that meet the Mn/DOT Mileage-based User Fees Demonstration Project requirements. These are presented in increasing technology order.

1. Manual – Self-recording, with mail-in / telephone call / web-based reporting
2. Manual – Project staff recording with handheld device
3. OBDII – Carchip (Davis Instruments) with project staff swap or download, or mail out/back swap

4. GPS / Memory Card – GD30-L (Laipac) memory cards swapped by project staff or participant mail-in

5. GPS and cellular
   - TrackBox (Airo / Benefon)
   - eDevice (IBM)

The manual methods are neither appealing nor appropriate for a large-scale study that is dependent upon the accurate collection of trip-level details such as mileage and travel times. Table 8 shows the key attributes of each of the potential technology solutions for comparison purposes.

The Carchip OBDII sensor is the least expensive option that meets the mileage and time of day requirements of the Mn/DOT study. Examples of data available from the Carchip appear in Appendix D. The other three options, all of which include a GPS component, enable location-based pricing, but at a considerably higher cost than the Carchip solution. Of the three GPS solutions, the GD30-L with its memory card method for data transfer has the lowest unit cost and is available now. However, this solution is susceptible to memory card losses and may introduce challenges to memory card access once the unit is installed. The GPS and cellular solutions are appealing for the full automation of data collection, transfer, and processing that they provide; however, there are significant technology challenges and costs associated with these solutions. Therefore, the Carchip OBDII sensor is the best choice among these recommendations when considering project requirements, scheduling, and cost.

Table 8: Summary Chart of Recommended Technology Solutions

	Carchip / Davis Instruments	GD30-L / Laipac Tech	eDevice / IBM Celestica	Trackbox / Airo Benefon
Technology	OBDII	GPS / Memory Card	GPS / Cellular	GPS / Cellular
Key Features	○ Plugs into ODB II port ○ Records trip start and end times and mileage for 75 or 300 driving hours ○ Records installation and removal times ○ Logs five-second speeds for every trip ○ Offload data using serial cable	○ GPS data recorder with memory card technology ○ Attached to vehicle interior via mounting bracket ○ Includes GPS patch antenna and power cable ○ Offload data by swapping memory cards	○ GPS logging with cellular transmission ○ Can record GPS speed and location data ○ To be used in Norwich Union mileage-based insurance fee demo ○ Four connections: GPS and cellular antennae, power, ignition sensor	○ Built-in GPS logging and cellular transmission ○ Records GPS points based on user-defined rules ○ Already deployed in US in other applications ○ Three connections: GPS antenna, power, ignition sensor
Size	1.3” x 1.9” x 1”	3.7” x 5.3” x 1.8”	3.5” x 5.5” x 1.3”	2.0: x 5.7” x 1.3”
Data Storage	75 or 300 operating hours	32 MB Memory Card	16 MB on unit	1 MB on unit
Unit Cost (in quantity)	$125 or $161	$225	$400	$450
Other Costs	○ Labor to download ○ Shipping costs if mail out / back	○ Extra memory cards ○ Labor to swap / download	○ Data transmission / setup ○ System integration ○ Data storage / setup	○ Data transmission / setup ○ Data storage / setup ○ Patch GPS antenna
Advantages	○ Very easy to install ○ Out of participant view ○ Available now	○ Swappable cards ○ High level of data detail ○ Available now	○ No field visits ○ GPS with wireless ○ IBM eager for US pilot	○ Small form factor ○ Cellular/GPS data expertise ○ Competitively priced, eager
Disadvantages	○ No GPS location data ○ No wireless transfer ○ 1996 and later vehicles only	○ Cards can be lost or damaged ○ No wireless capability ○ MC access may be challenging depending on install location	○ Not immediately available ○ Software development required ○ System integration costs (could be substantial) ○ Data transmission costs (HLOD)	○ Company based in Finland ○ Customization required ○ Data transmission costs (HLOD)

APPENDIX A FHWA Value Pricing Pilot Program Related Studies

The Transportation Equity Act for the 21st Century (TEA-21) authorized the Secretary of Transportation to create a Value Pricing Pilot Program (VPPP) in which up to 15 state or local governments (or other public authorities) would establish, maintain, and monitor local value pricing pilot programs. A total of $51 million was provided for fiscal years 1999-2003 for this program. According to the VPPP website, a total of 39 project grant awards were made for fiscal years 1999-2002. A review of these projects revealed four other studies in which mileage-based user fees were / are under consideration. A summary of the technology components of these studies is provided here.

California – San Francisco "City CarShare"

Agency: City of San Francisco
Type: Car Sharing
Objective: reduce regional VMT by providing 'shared' vehicles for short-term leasing
Date: 2001 - ongoing
Technology: Special cars, RF, Cellular, and on-board computer
Assessment: The car sharing technology is a viable value-pricing technology solution for broad implementation beyond station cars. The onboard computer sends and receives information regarding car use to a central computer that generates bills. Users are given a wireless key chain that holds the RF tag to communicate with the vehicle. Use statistics (mileage, time) are calculated for each use and sent to a billing account. Drivers are sent a monthly bill. The existing equipment package is mass-produced for car sharing services such as those offered by Flexcar and Zipcar. These vendors have expressed reluctance in adapting their equipment to meet the demands of reduced scope pilot studies such as mileage-based user fee studies.

Georgia – Atlanta Mileage-Based Insurance Study / FAIR Lanes / "Commute Atlanta"

Agency: GDOT
Type: Investigation into variable insurance pricing based on road use and its impact on travel behavior
Objective: Show that variable use costs can reduce household VMT
Date: 2002 - Ongoing
Technology: GPS / Cellular / OBD
Assessment: This project is in the early stage of implementation with Georgia Tech as the prime contractor. A total of 275 households (500 vehicles) are planned for deployment in the study. Equipment will be installed into vehicles for two years, with the first year serving for baseline behavior assessment. During the second year, variable insurance rates will be provided. The equipment package for tracking will be professionally installed and communicates at regular intervals to a central computer using digital cellular technology. With this equipment package, mileage, location, and vehicle operating parameters can be identified.

Oregon – Oregon's Mileage-Based Road User Fee Evaluation

Agency: ODOT
Type: Alternative revenue collection system evaluation
Objective: Explore and identify technologies for replacing the state's fuel tax
Date: 2002 - Ongoing
Technology: A variety of technology options are currently under evaluation

1. GPS / Cellular
2. GPS / RF Tag / Service Station
3. RF / Odometer Reader / Service Station
4. RF / Service Station
5. RF / RF Reader (spot tolling)

Assessment: Conclusions are not available as the project technology evaluation is ongoing. However, the initial technology investigation summarized that:

- GPS is the most expensive solution
- Privacy issues are a concern with GPS-based solutions
- RF technology combinations are not available commercially
- Fuel dispenser technologies have substantial costs

This project provides for a wide assessment of technologies in measuring vehicle usage using on-board equipment and/or remote capture. In their initial discussions, they are shying away from the use of GPS because of cost and the fact that it provides more information necessary for capturing mileage. Communication of information from vehicles has also been reviewed. Collection of RF Tag data at service stations has been studied and has been given positive reviews. An initial review suggests that an enhanced odometer reading device with RF tags and service station readers will probably be the best alternative of the five basic approaches.

Washington – Puget Sound GPS-Based Pricing Pilot Project

Agency: WSDOT / Puget Sound Regional Council
Type: Pilot project investigating the use of GPS in value pricing
Objective: Implement a facility-based pricing system to evaluate impact of pricing on travel behavior
Date: 2003 - On-going
Technology: GPS solutions are being investigated.
Assessment: This project is still early in development and no conclusions are available. It is clear that the project sponsors elected a GPS-based solution due to the fact that facility-based pricing was desired. GPS provides the ability to determine the amount and time of travel by facility. Communication of GPS recorded travel (stored in raw data or generalized in some manner) is expected to occur using digital cellular transmissions.

APPENDIX B NON-GPS Technology Solutions

AT5770 Odometer Tag / TransCore

Description: The AT5770 is a single-frame dynamic tag designed for use on vehicle exteriors. This device interfaces with the vehicle's speed sensor (VSS) and keeps track of the current mileage, with a resolution of 0.1 mile. It can communicate with existing toll tag reading RF sites, returning a vehicle identification code along with the accumulated mileage.
Assessment: The equipment is relatively simple and relies on an industry-proven communications method. Vehicle mileage could be collected using a system of tag readers located within / across the study area, although the readers are expensive and would require some communications device to transfer data to central location. Since these tags work via the VSS connection, they can only work in 1994 and later model years.
Requires Calibration: Yes
Power: 12 V DC
Operating temperature: -40° to +85° C
Technology: VSS
Communication Method: RF (900 MHz)
Website: www.transcore.com
Cost: between $50 to $100 per tag, plus at least $10,000 per reader, plus reader transmission hardware and costs

AutoWatch / EASE Diagnostics

Description: Plugs to the OBD II port and records vehicle activity (key on/off, distance traveled, trip duration, maximum speed and the last 20 seconds of vehicle speeds)
Assessment: The equipment records the minimum required information for mileage tracking. The maximum number of recorded events yields an approximate logging capacity of about 30 days. Reducing the number of recorded data elements might extend the logging capacity. Equipment requires physical connection to download data. It requires 1996 and later model year to record mileage.
Requires Calibration: No
Power: 12 V DC
Operating temperature: No specs available yet, but according to a sales representative, the unit has performed well in a wide range of temperature environments (e.g., Alaska and Saudi Arabia)
Technology: OBD II
Communication Method: RS 232 cable
Website: www.obd2.com
Cost: $350 (volume discounts available)

Carchip EX / Davis Instruments

Description: Plugs to the OBD II port and records up to 300 hours of vehicle activity. The user can program sampling frequency and up to four engine parameters to record. Trip start and end times, along with mileage, are automatically collected.
Assessment: This device automatically collects trip details including start and end times and mileage. The 300 hours of recording capacity will collect 100 days of activity assuming 3 hours of travel per day. It requires 1996 and later model year to record mileage.
Requires Calibration: No
Power: 12V (through OBD port), internal power 10-15 year battery
Operating temperature: -40° to +185°F
Technology: OBD II
Accuracy: Speed - 0 .6 mph, Distance - 0 .1 mile, Time - +/- 2 seconds per day
Size: 1.3 x 1.9 x 1 (inches)
Communication Method: RS 232 cable with power
Website: www.davisnet.com
Cost: $179 for 300 operating hours / $139 for 75 operating hours (volume discounts available)

DataTrak / Stemco

Description: Mileage tracker that attaches to wheel of heavy-duty vehicle using a mounting bracket.
Assessment: Not suitable for personal automobiles.
Requires Calibration: No, but different models are available based on vehicle make, model, and tire size.
Power: Battery
Operating temperature: No information
Technology: Hubodometer
Communication Method: Display only
Website: www.stemco.com
Cost: NA

Mobile Minion / AFX Technology Group International Inc.

Description: Can read the VSS signals and transmit data to land stations or to other equipped vehicles, using them as a peer-to-peer network.
Assessment: The equipment deployment would require substation communications software development and a minimum infrastructure in order to work. It requires 1994 and later model year to record mileage.
Requires Calibration: Yes
Power: 3 V removable or replaceable batteries; can be customized to be externally powered
Operating temperature: -40° to + 85°C
Technology: VSS
Communication Method: Wireless LAN technology, includes peer-to-peer communications using 900 MHz frequency band.
Size: 2.4 x 3.7 x 1.0 (inches)
Website: www.afxtech.com
Cost: $180 / Mobile minion device (will provide volume discount) + 200.00 / Fixed Minion reader

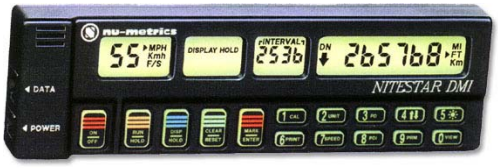
Mileage Keeper / Wilderness Technology

Description: This product is suitable for fleet management applications, where the mileage for each trip along with trip detail must be recorded for accounting and IRS purposes. It connects to the vehicle's OBD II interface and is capable of recording up to 500 trips (~50 days with 10 trips a day). The equipment features a user interface and requires input on each trip that is started. The device's data can be downloaded to a computer via a serial communications port.
Assessment: The user interface requirements of the equipment would most likely become a burden to participants and hamper the results of the study. According to information in the web site, this interface could be installed behind the dash and the device would still record Mileage in the background. The need for a physical connection to obtain the data also makes its deployment problematic.
Requires Calibration: Yes
Power: Connects to vehicle's speedometer pickup and battery with a small 4 wire cable.
Technology: VSS
Communication Method: RS 232 Cable
Size: 7 x 5.25 x 1.5 (inches)
Website: www.wildtec.com
Cost: $339

Mileage Master / Mileage Master

Description: This is solution is very similar to the Mileage Keeper. It is advertised for the same applications and uses similar technology. It also has similar limitations.
Assessment: It is basically the same solution as the Mileage Keeper, only at a lower cost.
Requires Calibration: Yes
Power: 12V (hardwired into vehicle power source)
Technology: VSS
Communication Method: RS 232 Cable
Website: www.mileagemaster.com
Cost: $269

NITESTAR 50 / NuMetrics



Description: This equipment is manufactured by NuMetrics and is used for measuring length of highways, guardrails, school bus routes, telephone pole spacing, gas pipelines, etc.
Assessment: Too sophisticated for the envisioned use, lacks wireless communications and is size intrusive.
Requires calibration: yes
Power: 12V (hardwire into vehicle power source)
Operating temperature: 0°C to 70°C
Technology: DMI.
Communication Method: RS 232 cable
Accuracy: +/- 1 foot per mile
Size: 7.5 x 2.25 x .88 (inches)
Website: www.nu-metrics.com
Cost: $340 (will provide volume discount)

Tacholink Black Box / Circuitlink International

Description: This device is a VSS-like data logger and event data recorder that connects to the vehicles ignition and tachometer, converting pulses from the tachometer into mileage. The unit stores and transfers data using a "Download Smart Module" (DSM), a type of memory card. This card can store 16 Mb of data (approximately 25 days of driving data).
Assessment: The drawback of this device is the calibration it would require to operate with the odometer/tachometer of American cars (according to a company representative). In addition, it is an expensive device.
Requires calibration: yes
Power: hard-wired to vehicle

Operating temperature: -15° to +80°C
Technology: VSS
Communication Method: Memory card
Accuracy: 0.01% deviation from 100% accurate
Size: no dimensions were available, but fits in the palm of the hand, according to a company representative.
Website: http://www.circuitlink.com.au/
Cost: $380 / unit for 400 units

Zipcar

Description: Hourly, reservation-based automobile service with Smart Card technology for wireless vehicle access. Usage information is transmitted through cellular link (CDPD) and monthly charges are automatically applied to a credit or debit card.
Assessment: This product has a high level of automation and offers much more than what is need for the Mn/DOT study.
Requires Calibration: No, but installation effort might be significant.
Technology: Custom black box with sensors, control unit, and cellular communications.
Communication Method: Cellular (CDPD)
Cost: $1200 / month includes vehicle, gas, insurance, and reservation (quote on phone); website shows hourly lease rates.
Vendor Comments: Not interested in modifying their system to accommodate reduced needs of this study; stated this would be too much effort and would be expensive.

APPENDIX C GPS Technology Solutions

Wired Transmission

GeoLogger / GeoStats

Description: An in-vehicle GPS data logger that is powered by the cigarette lighter socket of a vehicle, designed for travel surveys and travel time studies.
Assessment: Does not support wireless data transfer or memory card swapping, therefore would require frequent visits by field staff for downloading or logger swapping.
Required Modifications: Significant hardware change to support memory card or cellular communications.
Power: Could be powered directly from vehicle power source, but current design support cigarette lighter socket only.
Operating temperature: -30° C to +85° C
Communication Method: RS233 serial cable
Accuracy: Position Accuracy - Non-differential GPS: 15m RMS, 5 – 10m typical
Size: 2.6 x 4.4 x 1.1 (inches)
Website: www.geostats.com
Cost: $595 (quantity discounts available)

TravelEyes2 / Advanced Tracking Technologies, Inc

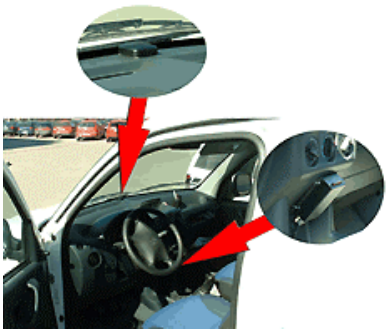
Description: The unit automatically gathers miles driven on a daily basis, maintains hourly billing records and produces comprehensive reports on all travel activities.
Assessment: Due to wired data transmission (i.e., must remove the unit to download data logged), this product may not be suitable for this project.
Power: 12 V DC
Operating temperature: No information
Communication Method: cable-PC
Accuracy: Distance – 10-50 ft.
Size: 3.38 x 2.0 x 0.98 (inches)
Website: www.traveleyes.com
Cost: $350

Memory Card Transmission

GD30-L / Laipac Tracking Solutions

Description: GPS recorder and vehicle tracking system with memory card technology for the storage of a large amount of GPS tracking data. The 32MB MMC card can record up to 400,000 GPS waypoints
Assessment: This product could log data for this project.
Required modifications: Few if any
Power: 5-12V DC with backup battery capability
Communication Method: memory card
Accuracy: Distance – 29 feet, Time - 1 Hz/sec update, 1804 f/sec maximum
Size: 3.7 x 5.3 x 1.8 (inches)
Website: www.laipac.com/gps_gd30l_eng.htm
Cost: $225

TracWise I / Hamilton Global Management



Description: A GPS data logging module supplied by Hamilton Global Management that uses a compact flash memory card.
Assessment: A simple, effective data-logger, but not cost-effective for this project.
Required Modifications: No information
Power: cigarette lighter socket or direct 12V vehicle power
Communication Method: Compact Flash memory card
Accuracy: Distance- 25m CEP, Speed :0.1/sec, Time - ±1µs
Size: 1.4 x 3.5 x 5 (inches)
Website: www.tracwise.com
Cost: $725

VBOX II Lite / Racelogic

Description: A UK-based company that manufactures GPS data logging products.
Assessment: Their devices appear to be geared towards the racing community (the instruments are designed primarily to measure *extremely precise* speed position and velocity), in addition, this unit is designed to store data for short increments of time (e.g., one hour or less).
Required modifications: This product would require mileage-based logging logic modifications.
Power: No information
Communication Method: Compact Flash memory card
Accuracy: Distance – 1 cm, Speed - 0.006 mph, Time -1 second
Website: www.racelogic.co.uk
Cost: No information available

Wireless Transmission

Aertrax III / AerComTec International

Description: (**Aertrax™ III**) Field units may be programmed to transmit Global Positioning System (GPS) location data on either a regular, timed basis, or in response to a specific command from your computer -- or a combination of both methods. No dedicated hardware or software is required to operate its system.
Assessment: Aertrax units may be installed with no technical training necessary. A desktop PC or laptop with Internet access is all that is necessary to operate the system. Not cost-effective for this project
Required Modifications: None could be made
Power: 12 V DC + 2.0 A standby
Operating temperature: -10° to +65°C
Method of Data storage: online
Communication Method: Cellemetry Data Service- cellular antenna
Accuracy: Distance – 9 feet
Size: 5 x 3.5 x 1.5 (inches) 1.5 lbs
Website: www.aercomtec.com
Cost: $679 + ~30.00/month service fee

Aertrax V / AerComTec International

Description: An OBU (with antenna) that can provide location, mileage, start-stop times in real-time that does not require dedicated hardware or software. Data is transmitted wireless through Control Channel Data, which can then be accessed via the internet.
Assessment: Appears to be similar to the Aertrax III except for the method of data transmission (cellular for Aertrax III, RF for Aertrax V).
Required Modifications: None could be made.
Power: 12 V DC, with optional backup battery assembly
Operating temperature: -30° to +60°C
Method of Data Storage: 8MB on unit, or remote storage
Communication Method: AMPS control channel data certified, 800 MHz operational frequencies
Accuracy: +/– 50 feet
Size: 6.09 x 4.07 x 1.04 (inches)
Website: www.aercomtec.com
Cost: $395 (>21 units) ~30.00/month service fee

BBX / Mentor Engineering

Description: Sends data over wireless networks or acts as standalone data collector. The Mentor system can automatically gather data in real-time, over wireless links. Or, Smart Cards and large capacity memory cards can be used to capture information for later analysis
Assessment: According to a company representative, this product is probably not cost effective for this project, but a device could be customized.
Required modifications: This device can be customized for mileage-based logging logic.
Power: 12 V DC
Operating temperature: -30° to 65° C
Technology: (BBX unit) 12 channel GPS receiver with WAAS capability.
Communication Method: Integrated public data modem options including: CDPD, GSM (SMS), GPRS, Mobitex, EDACS, iDEN (Nextel), DataTac
Size: 4.75 x 5.0 (inches)
Website: http://www.mentoreng.com/products/bbx.htm
Cost: variable

eDevice / IBM Celestica

Description: These electronic monitoring devices for cars are being promoted as black boxes based upon industry open standards. They will wirelessly transmit information from vehicles to specific databases, providing information on a wide range of variables including speed, location, or use of seatbelts – entirely as specified by each customer.
Assessment: This product looks promising, although it is not commercially available yet and we are still waiting on product details, availability, and cost. One pilot program that is underway will use the eDevice for a "Pay-As-You-Drive" pilot insurance program offered by Norwich Union, the UK's largest auto insurer.
Required Modifications: minor
Power: 12V DC
Communication Method: GSM/GPRS modem
Website: www-1.ibm.com/industries/automotive/doc/content/news/pressrelease/875975108.html
Cost: $400 each plus transmission / central storage /system integration costs

Fleet Real-time Tracker / 123 Vehicle Tracking

Description: This system transmits location information via an AMS cellular modem to a control center.
Assessment: More appropriate for fleet tracking applications, it is also very expensive.
Required Modifications: This product would require logging logic modifications.
Communication Method: cellular modem
Website: www.123-vehicle-tracking.com
Cost: $600-$1700

GeoManager *i*LM / @Road

Description: A company that provides customizable mobile resource management services using the internet, location technologies (GPS/GIS), wireless communication, and patented software/hardware
Assessment: May not be appropriate for this project due to sophisticated capability for tracking. In addition, this device has small capacity for storage of data (website recommends data be transferred to central facility every 15 minutes)
Required Modifications: Must be modified for mileage-logging logic
Power: hard-wired into vehicles battery
Operating temperature: No response
Communication Method: cellular modem
Accuracy: Distance - 200 feet
Size: small book
Website: www.@road.com
Cost: $699 / unit for 400 units + ~40.00/month for cell service contract

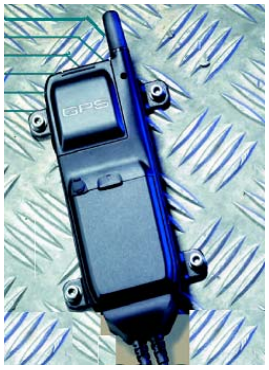
Shadow Tracker 2000 / Advanced Tracking Technologies

Description: OBU with GPS-based logging/tracking capabilities with automatic wireless data transfer capabilities. Requires Shadow Tracker software and base station connected to computer to receive wireless data transfer.
Assessment: Is not cost-effective for this project.
Required Modifications: None could be made
Power: 12 V DC
Operating temperature: -20° to 70°C
Method of Data Storage: 512 KB storage capability on unit, long-term storage on main computer
Size: 1 x 4 x 6 (inches)
Communication Method: 900MHz radio transmission
Website: http://www.advantrack.com/
Cost: $1600

The Starfinder AVL / Laipac Tracking Solutions

Description: The StarFinder is a compact real-time GPS receiver/data logger. This Automatic Vehicle Location (AVL) system is designed to connect with GSM/GPRS, CDMA/1X or 2 way pager networks and LTR Fleetsync radio. "GPS Wedge" GIS software is required.
Assessment: This device is not cost-effective for this project.
Power: 12 V DC
Operating temperature: -20° to 70° C
Method of Data Storage: 512 KB internal flash storage
Communication Method: GSM/GPRS, CDMA and LTR Fleetsync radio capability
Accuracy: Distance: 10 feet
Size: 4.4 x 6 x 1 (inches)
Website: http://www.laipac.com/gps_starfinder1_eng.htm
Cost: $860 plus transmission costs

Trackbox / Airo Benefon



Description: A cellphone-like product with built in GPS logging and cellular transmission using the GSM cellular network. An emergency call button can be activated to send an emergency message with GPS coordinates.
Assessment: This product has a small profile and is somewhat easy to install. The device is designed for GPS logging and data transmission.
Required Modifications: Increased storage capability between downloads and mileage-based logging logic.
Power: 10–30V DC input, backup - standard 650 or 1700 mAh Li-ion battery
Operating temperature: –22° to +55°C
Communication Method: GSM cellular network
Size: 5.7 x 2 x 1.3 (inches)
Website: www.benefon.com/usa
Cost: $450 each plus transmission / central storage costs

VLM-100 / TransTel Group Inc.

Description: Collects and transmits vehicle location information as well as voice and data communication between dispatch center and vehicle. An emergency call button can be activated to send an emergency message with GPS coordinates.
Assessment: This telematics product is very typical of the GPS and cellular capabilities available on the marketplace today. As a small company, they are willing to modify device for Mn/DOT project. However, they are not price competitive.
Required Modifications: mileage-based logging logic.
Power: 12 V DC
Operating temperature: "The unit is designed to withstand the range of temperatures and voltage surges that are typically encountered in commercial vehicles" (from website)
Communication Method: GSM, TDMA, or CDMA cellular network
Website: www.transtelgroup.com
Cost: $800 each plus transmission / central storage costs

Other Manufacturers / Suppliers Considered

Pinpoint / AirLink

Description: This device can be configured to report its position by time and/or distance.
Assessment: This product was one of those evaluated by the CLF Ventures Value Pricing Program team. There has been no response from this vendor.
Required Modifications: No response
Communication Method: CDPD communications network
Website: www.airlinktracking.com

Telematics Systems / Vetronix

Description: This set of solutions offers a full suite of products tailored to support asset management, fuel tracking, driver / fleet productivity and logistics, vehicle service and maintenance with remote diagnostics, and safety and security.
Assessment: Vetronix is the provider of Flexcar's in-vehicle instrumentation package. After discussions with Martin Abott of Vetronix, it appears that their solutions, including the Flexcar solution, offer much more than what is needed for the Mn/DOT study.
Required Modifications: Significant scale down of functionality
Communication Method: Mobitex (Cingular), GPRS/GSM cellular networks
Website: www.vetronix.com
Vendor Comments: Not interested in modifying their system to accommodate reduced needs of this study; stated this would be too much effort and would be expensive.

Trip Data Collector (TDC) / Altius Solutions

Description: Developed for clients GA Tech and MIT, who assisted in the development of this data collection device specifically for comprehensive vehicle trip data collection and analysis. It can be used to capture and transmit relevant vehicle trip data such as GPS coordinates, mileage, start and stop times, and onboard computer data.
Assessment: This product is most likely similar to that being used in the Atlanta Value Pricing Project sponsored by the FHWA, and could be a good fit for the Mn/DOT project. However, GA Tech is currently negotiating with a third party provider for release later this year, with their 'system' offered on a 'fee for service' basis. Therefore, it is not likely that the equipment itself will be available for this study.
Required Modifications: No response
Communication Method: TDMA cellular network
Website: www.altiusllc.com

APPENDIX D Example Carchip Reports

View / Activity Log / Summary

	Time	CarChip	Description
Event 1	7/21/2003 9:08 AM	J-4013-A	Cleared.
Event 2	7/22/2003 6:48 PM	J-4013-A	Disconnected.
Event 3	7/22/2003 6:48 PM	J-4013-A	Connected to Audi A4 2001.
Event 4	7/23/2003 7:50 AM	J-4013-A	Disconnected.
Event 5	7/23/2003 8:02 AM	J-4013-A	Logs downloaded.

View / Trip Log / Summary

	Start Time	Duration	Distance Miles	Maximum Speed MPH	Time in Top Speed Band	Brakes Hard	Brakes Extreme	Accelerations Hard	Accelerations Extreme	Vehicle
Trip 1	7/22/2003 6:48 PM	0:21:58	8.0	63	0:00:00	5	0	2	0	Audi A4 2001
Trip 2	7/23/2003 7:23 AM	0:27:07	7.5	48	0:00:00	2	0	4	0	Audi A4 2001

	Elapsed Time	Speed MPH	Engine Speed RPM	Throttle Position %	Engine Load %
1	0:00:00	0	1,174	23.92	14.12
2	0:00:05	6	1,561	11.76	10.59
3	0:00:10	15	2,033	15.69	16.09
4	0:00:15	19	1,341	12.55	8.63
5	0:00:20	18	1,445	5.88	3.53
6	0:00:25	14	938	10.59	8.63
7	0:00:30	7	1,856	38.43	23.53
8	0:00:35	15	2,549	38.43	35.29